University of Banja Luka
Faculty of Mechanical Engineering

# DEMI 2021

## 15th International Conference on Accomplishments in Mechanical and Industrial Engineering

# PROCEEDINGS

Banja Luka, 28 - 29 May 2021

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Faculty of Mechanical Engineering

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*Banja Luka, May 2021*

# 15th INTERNATIONAL CONFERENCE ON ACCOMPLISHMENTS IN MECHANICAL AND INDUSTRIAL ENGINEERING

## DEMI 2021

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**CONTENT**

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# Energy Management To Low-Carbon Cities: the Example of the City of Kragujevac

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***Abstract*** *Serbia first ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 2001, and then the Paris Agreement in 2017. By ratifying the Paris Agreement, Serbia has committed to reduce greenhouse gas emissions by 9.8% by 2030, compared to 1990 level of emissions. As cities are responsible for over 70% of all GHG emissions, they are becoming a main place to act and combat climate change and reduce GHG emissions. In Serbia, there is a legal obligation of cities and municipalities to establish a system of energy management (SEM). The city of Kragujevac established the SEM in 2015. The paper gives an overview of energy efficiency measures implemented in this period and how the measures have affected the reduction of $CO_2$ emissions, and thus the decarbonization of the city.*

***Keywords*** *Energy management, Energy planning, Low-Carbon Cities, energy efficiency measures*

## 1. INTRODUCTION

Today, approximately 72% of the total population of the European Union lives in larger and smaller cities and suburbs. Although the rate of change is slowing, the share of the population living in cities continues to grow and is likely to reach more than 80% by 2050 [1]. Cities consume over two-thirds of the total amount of energy consumed worldwide. Over 70% of all greenhouse gases (hereinafter: GHG) emissions originate from cities [2].

There are a number of plans and strategies in the European Union related to reducing $CO_2$ emissions. Some of these plans until 2050 are presented in two strategic documents: Energy Roadmap 2050 and A Roadmap for moving to a competitive low carbon economy in 2050, and they foresee targets for reducing greenhouse gases by 80-95% compared to the baseline year of 1990 [3].

The Covenant of Mayors (CoM) is a successful European initiative which encourages local authorities to be proactive in fighting climate change. The methodology is applied to over 1600 signatories in Europe, representing over 80 million inhabitants

Signatory cities pledge actions to support the implementation of the 40% greenhouse gas-reduction target by 2030. For a baseline year of their choice, summarising energy consumption and $CO_2$ emissions for different sectors and fuels (referred to as energy carriers).

The EU Covenant of Mayors (CoM) is an international initiative, part of the Global Covenant of Mayors, that directly engages local governments to adopt climate and energy targets at least matching the EU targets. By voluntarily adhering to the CoM, local authorities committed to decarbonise and increase resilience in their territory and share their emission inventories and climate action plans [4].

In the case of the city of Kragujevac, the highest emissions are the result of the energy consumption in public buildings - 49%, public

lighting - 36% and public transport - 15% [5]. The last document adopted in the Republic of Serbia that deals with GHG emissions is the Law on Climate Change [6], adopted in March 2021. This law regulates, among other things, the system for limiting the GHG and for adapting to changed climatic conditions, monitoring and reporting on the low-carbon development strategy and its improvement. GHGs are carbon dioxide (CO2), methane (CH4), nitrogen suboxide (N2O), fluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) and nitrogen trifluoride (NF3).

The aim of this law is to establish a system to reduce GHG emissions in a cost-effective and economically efficient manner, thus contributing to the achievement of scientifically necessary levels of GHG emissions, to avoid dangerous global climate change and adverse impacts of climate change, reducing GHG emissions and adapting to changed climate conditions through the adoption and implementation of public policy documents, the establishment of mechanisms for timely, transparent, accurate, consistent, comparable and complete reporting and verification of information on compliance with the Law on Ratification of the UN Framework Convention on Climate Change (with annexes), the Law on Ratification of the Kyoto Protocol, the Law on Ratification of the Doha Amendments to the Kyoto Protocol with the United Nations Framework Convention on Climate Change and the Law on Ratification of the Paris Agreement, as well as the Monitoring and Reporting of GHG Emissions from Human Sources and removed by sinks and adapted climate change activities conditions undertaken in a cost-effective and economically efficient manner. In order to achieve the objectives of this law, state bodies and organizations should adopt appropriate sectoral policies and measures within the scope of their competence.

In the forthcoming period, the Low Carbon Development Strategy will be adopted in order to determine strategic directions of action and public policy related to the limits of GHG emissions from sources, as well as transparent and accurate monitoring of the achievement of these emission limits.

The law further addresses vehicle fuel consumption and $CO_2$ emissions, GHG emissions from installations and aeronautical activities, the system for monitoring and reporting on national GHG emissions, projections of GHG emissions from sources and removals by sinks, the system for reporting on GHG policies, measures and projections, administrative fees, supervision and penal provisions.

Until bylaws dealing with various sectors, including buildings, which are one of the biggest causes of $CO_2$ emissions, are adopted, local self-governments in Serbia are left to implement energy policy, the introduction of energy management systems and energy planning as one of the ways to reduce GHG emissions, primarily $CO_2$ emissions.

The paper further analyzes how the introduction of an energy management system can lead to a reduction of $CO_2$ emissions.

## 2. ORGANIZATION OF CITIES IN SERBIA IN THE FIELD OF ENERGY MANAGEMENT

Starting in 2006, when the local government units were supposed to submit energy balance sheets to the Ministry of Mining and Energy for the first time, cities and municipalities appointed persons who started dealing with energy efficiency issues in some way. In these first reports, in addition to energy consumption in public buildings, $CO_2$ emissions were also shown.

### 2.1 Legal framework for the energy management system in RS

According to the Law on Efficient Use of Energy [7], all local government units with more than 20,000 inhabitants have an obligation to appoint an energy manager.

### 2.2 Organization of Cities in Serbia in the Field of Energy Management

In the cities and municipalities in Serbia, organization of the energy management system is different from place to place, as is a number of employees in these jobs and appointed energy managers. Thus, in Novi Sad, there is the Energy Agency, which employs an energy manager, while in Belgrade it's the Energy Secretariat, and in Niš, the City Assembly appoints an energy manager, and there is a department that deals with these issues. In other cities and municipalities mainly only one person - energy manager - deals with activities related to energy

efficiency, greater use of renewable energy sources, and thus reduction of GHG emissions.

### 2.3 Organization of the City of Kragujevac in the Field of Energy Management

In accordance with the Law on Efficient Use of Energy, the city of Kragujevac appointed an energy manager in 2016.
According to the Law on Efficient Use of Energy, the energy manager:

1. Collects and analyzes data on the energy use by the SEM payers
2. Drafts the energy efficiency program and plan to be adopted by the City of Kragujevac
3. Submits annual reports on the achievement of the objectives contained in the energy efficiency program and plan to the relevant Ministry
4. Proposes measures that contribute to the efficient use of energy and participates in their implementation

During 2015, the Department for Energy Efficiency was formed, and after the reorganization of the city administration in 2020, there is a Department for project management and energy efficiency. The main task of the Department is also to monitor and analyze energy consumption and propose energy efficiency measures.

### 2.4 Results of the Established Energy Management System in Kragujevac

#### 2.4.1 Measures Implemented on the Primary and Secondary Schools' Facilities

The paper analyzes measures in primary and secondary schools.
In the period from 2015 to 2020, the following measures were implemented at school facilities:

1. Installation of thermoregulatory equipment
2. Replacement of carpentry
3. Combined measures: replacement of carpentry and installation of thermoregulation equipment
4. Combined measures: replacement of carpentry, insulation of building walls and installation of thermoregulation equipment

Combined measures: replacement of carpentry, insulation of building walls, replacement of LED lighting, measures on the district heating system (the reference year is 2015).

**Table 1.** Energy efficiency measures implemented in schools

| | Name of School | Implemented energy efficiency measures |
|---|---|---|
| | **Primary schools** | |
| 1. | PS "21. Oktobar" | Installation of thermoregulatory equipment |
| 2. | PS "Sveti Sava" | Installation of thermoregulatory equipment |
| 3. | PS "Svetozar Marković" | Installation of thermoregulatory equipment |
| 4. | PS "Mirko Jovanović" | Installation of thermoregulatory equipment |
| 5. | PS "Radoje Domanović" | Installation of thermoregulatory equipment |
| 6. | PS "Milutin i Draginja Todorović" | Replacement of carpentry and installation of thermoregulatory equipment |
| 7. | PS "19.oktobar" | Heating system change, insulation of building walls, replacement of carpentry |
| 8. | PS "Treći kragujevački bataljon" | Replacement of carpentry, insulation of building walls and installation of thermoregulatory equipment |
| 9. | PS "Dositej Obradović" | Replacement of carpentry |
| 10. | PS "Natalija Nana Nedoljković" | Replacement of carpentry |
| 11. | PS "Živadinka Divac" | Replacement of carpentry |
| 12. | PS "Vuk Stefanović Karadžić" | Replacement of carpentry |
| 13. | PS "Natalija Nana Nedeljković" | Replacement of carpentry |
| 14. | PS "Sveti Sava" | Replacement of carpentry |
| 15. | PS "Moma Stanojlović" | Replacement of carpentry, insulation of building walls, replacement of LED lighting, measures on the district heating system |
| 16. | PS "Stanislav Sremčević" | Replacement of carpentry, insulation of building walls, replacement of LED lighting, measures on the district heating system |
| | **Secondary schools** | |
| 1. | Second Kragujevac High School | Replacement of carpentry |
| 2. | Secondary Vocational School | Replacement of carpentry |
| 3. | First Technical School | Replacement of carpentry |
| 4. | "Toza Dragović" | Replacement of carpentry |

### 2.4.2 $CO_2$ emission in the baseline year

The base year was 2015, after which energy efficiency measures were implemented at the listed primary and secondary school facilities. Consumption data have been taken from the Energy Efficiency Program for the City of Kragujevac for the period 2018-2020 [8].
To calculate $CO_2$ emissions, the conversion factors given in Table 2 were used.

**Table 2.** Conversion factors for calculating $CO_2$ emission

| Fuel | Unit | kWh/jm | Emission kg/kWh |
|---|---|---|---|
| Raw lignite | t | 3.600,0000 | 0,35 |
| Dried lignite | t | 4.500,0000 | 0,35 |
| Brown coal | t | 5.000,0000 | 0,35 |
| Stone coal | t | 6.000,0000 | 0,35 |
| Coal – coke | t | 7.000,0000 | 0,35 |
| Wood | m3 | 1.680,0000 | 0,30 |
| Wood waste | t | 4.500,0000 | 0,30 |
| Biomass | t | 3.600,0000 | 0,35 |
| Heating oil | t | 4.500,0000 | 0,35 |
| Crude heating oil | t | 5.000,0000 | 0,35 |
| Propane-Butane | t | 6.000,0000 | 0,35 |
| Natural gas | t | 7.000,0000 | 0,35 |
| Biogas | $m^3$ | 1.680,0000 | 0,30 |
| Electricity | t | 4.500,0000 | 0,30 |
| Solar energy | t | 3.500,0000 | 0,30 |
| Geothermal water | m3 | 11.390,0000 | 0,25 |
| Wind energy | t | 11.000,0000 | 0,28 |

Tables 3, 4 and 5 provide an overview of $CO_2$ emissions [t] in primary and secondary schools for the baseline year 2015, before energy efficiency measures were implemented.

**Table 3:** $CO_2$ emission in primary schools for 2015

| | | |
|---|---|---|
| Primary schools – Year 2015 | Total $CO_2$ emission [t] | 7037 |
| | Heating-generated $CO_2$ emission [t] | 5368 |
| | Electricity-generated $CO_2$ emission [t] | 1669 |

**Table 4:** $CO_2$ emission in secondary schools for 2015

| | | |
|---|---|---|
| Secondary schools – Year 2015 | Total $CO_2$ emission [t] | 4159 |
| | Heating-generated $CO_2$ emission [t] | 3174 |
| | Electricity-generated $CO_2$ emission [t] | 985 |

**Table 5:** $CO_2$ emission in primary and secondary schools for 2015

| | | |
|---|---|---|
| Total primary and secondary schools – Year 2015 | Total $CO_2$ emission [t] | 11196 |
| | Heating-generated $CO_2$ emission [t] | 8542 |
| | Electricity-generated $CO_2$ emission [t] | 2654 |

Figure 1 shows the distribution of total $CO_2$ emissions in [%] in primary and secondary schools in 2015. It can be seen that the largest part of the emission comes from heating (76%).

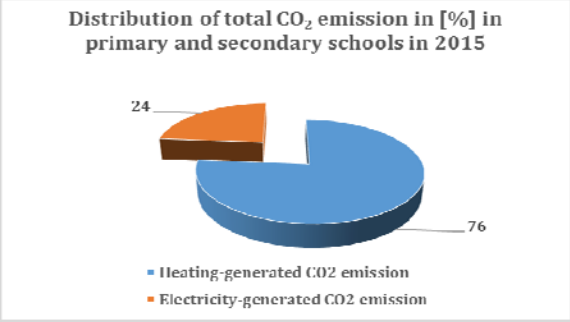


**Fig. 1.** Distribution of total $CO_2$ emissions [%] in primary and secondary schools in 2015

### 2.4.3 $CO_2$ emission in 2020

Tables 6, 7 and 8 show the emission in 2020, after the implemented measures.

**Table 6.** $CO_2$ emission in primary schools for 2020

| | | |
|---|---|---|
| Primary schools - Year 2020 | Total $CO_2$ emission [t] | 3294 |
| | Heating-generated $CO_2$ emission [t] | 2098 |
| | Electricity-generated $CO_2$ emission [t] | 1196 |

**Table 7:** $CO_2$ emission in secondary schools for 2020

| | | |
|---|---|---|
| Secondary schools - Year 2020 | Total $CO_2$ emission [t] | 1841 |
| | Heating-generated $CO_2$ emission [t] | 1306 |
| | Electricity-generated $CO_2$ emission [t] | 535 |

**Table 8:** $CO_2$ emission in primary and secondary schools for 2020

| | | |
|---|---|---|
| Total primary and secondary schools - Year 2020 | Total $CO_2$ emission [t] | 5135 |
| | Heating-generated $CO_2$ emission [t] | 3404 |
| | Electricity-generated $CO_2$ emission [t] | 1731 |

Figure 2 shows the distribution of total $CO_2$ emissions in [%] among primary and secondary schools in 2020. It can be seen that most of the emission still comes from heating (66%). As the largest part of the implemented measures referred to the measures on the district heating system, the ratio of emissions originating from heating and electricity was changed. It is now closer, which means that the following measures need to be implemented in order to save electricity. This can be the replacement of interior lighting with LED lighting or the installation of PV panels on the roofs of these buildings.

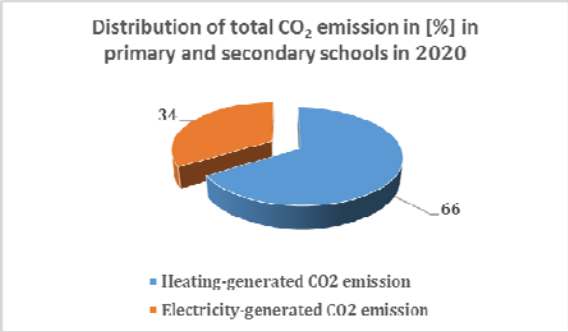


**Fig. 2.** Distribution of total $CO_2$ emissions in [%] among primary and secondary schools in 2020.

### 2.4.4 Reduction of $CO_2$ emissions caused by the implementation of measures in primary and secondary school buildings

Tables 9, 10 and 11 show the reduction of $CO_2$ emissions in primary and secondary schools in [t].

**Table 9.** Reduction of $CO_2$ emissions [t] in primary schools in the period 2015-2020

| | | |
|---|---|---|
| Reduction of $CO_2$ emission [t] in primary schools | Reduction of the total $CO_2$ emissions [t] | 3743 |
| | Reduction of the heating-generated $CO_2$ emissions [t] | 3270 |
| | Reduction of the electricity-generated $CO_2$ emissions [t] | 473 |

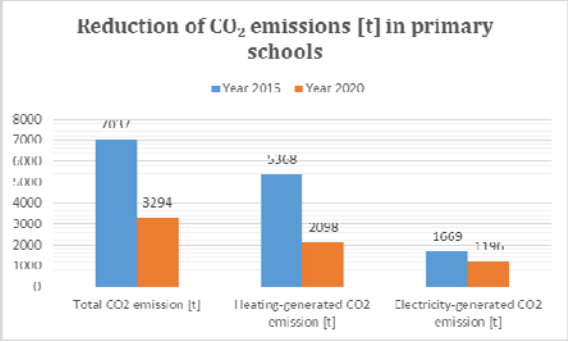


**Fig.3** Reduction of $CO_2$ emissions [t] in primary schools

**Table 10:** Reduction of $CO_2$ emissions [t] in secondary schools in the period 2015-2020

| | | |
|---|---|---|
| Reduction of $CO_2$ emissions [t] in secondary schools | Reduction of the total $CO_2$ emissions [t] | 2318 |
| | Reduction of the heating-generated $CO_2$ emissions [t] | 1868 |
| | Reduction of the electricity-generated $CO_2$ emissions [t] | 450 |

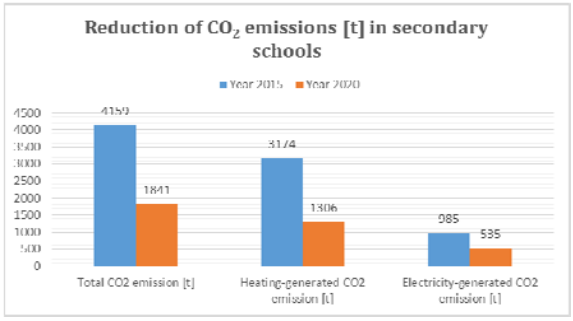


**Fig. 4.** Reduction of $CO_2$ emissions [t] in secondary schools

**Table 11:** Reduction of $CO_2$ emissions [t] in primary and secondary schools in the period 2015-2020

| | | |
|---|---|---|
| Total reduction of $CO_2$ emissions [t] in primary and secondary schools | Reduction of the total CO2 emissions [t] | 6061 |
| | Reduction of the heating-generated CO2 emissions [t] | 5138 |
| | Reduction of the electricity-generated CO2 emissions [t] | 923 |

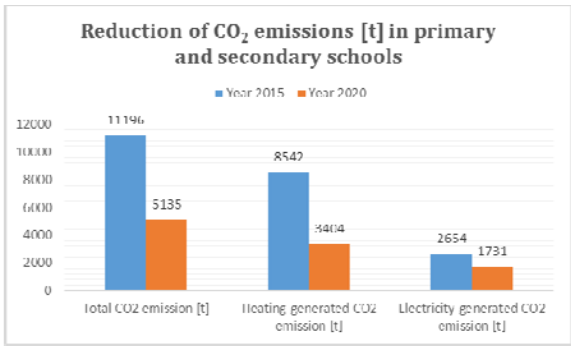


**Fig.5** Reduction of $CO_2$ emissions [t] in primary and secondary schools

Table 12 shows the percentage reduction of $CO_2$ emissions in primary and secondary schools in the period 2015-2020. The decrease was 53% in primary schools, 56% in secondary schools and 54% in total in primary and secondary schools.

**Table 12:** Reduction of $CO_2$ emissions in [%] in primary and secondary schools in the period 2015-2020

| | |
|---|---|
| Reduction of $CO_2$ emissions [%] in primary schools | 53 |
| Reduction of $CO_2$ emissions [%] in secondary schools | 56 |
| Total reduction of $CO_2$ emissions [%] in primary and secondary schools | 54 |

## 3. CONCLUSION

By ratifying the Paris Agreement, Serbia has committed itself to reducing greenhouse gas emissions by 9.8% by 2030 compared to 1990 levels. As cities are responsible for over 70% of all GHG emissions, they are becoming a major place to act and combat climate change and reduce GHG emissions. The implementation of energy efficiency measures in cities can significantly contribute to the reduction of $CO_2$ emissions. The introduction of energy management systems and the planning of energy efficiency measures in buildings lead to a reduction of $CO_2$ emissions by 53-56%.

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